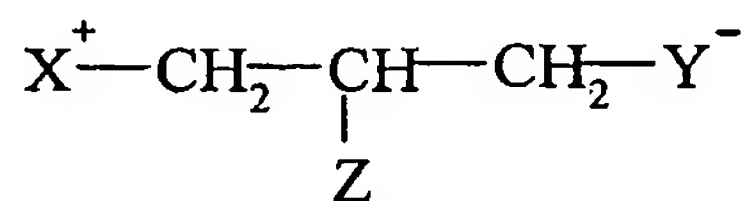10/585972

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COMPOUNDS HAVING ANTITUMOR ACTIVITY

The present invention relates to a new class of compounds having antitumor activity. Specifically the invention provides the use of compounds of general formula (I):

$$X^+ \!\!-\!\! CH_2 \!\!-\!\! \underset{\underset{Z}{|}}{CH} \!\!-\!\! CH_2 \!\!-\!\! Y^-$$

(I)

wherein X^+ is selected from the group consisting of $N^+(R_1, R_2, R_3)$ and $P^+(R_1, R_2, R_3)$, wherein R_1, R_2 and R_3, which are the same or different, are selected from the group consisting of hydrogen and C_1-C_9 straight or branched alkyl groups, $-CH=NH(NH_2)$, $-NH_2$, $-OH$; or two or more R_1, R_2 and R_3, together with the nitrogen atom which they are linked to, form a saturated or unsaturated, monocyclic or bicyclic heterocyclic system; with the proviso that at least one of R_1, R_2 and R_3 is different from hydrogen;

Z is selected from

$-OR_4$,

$-OCOOR_4$,

$-OCONHR_4$,

$-OCSNHR_4$,

$-OCSOR_4$,

$-NHR_4$,

$-NHCOR_4$,

$-NHCSR_4$,

$-NHCOOR_4$,

$-NHCSOR_4$,

$-NHCONHR_4$,

$-NHCSNHR_4$,

-NHSOR$_4$,

-NHSONHR$_4$,

-NHSO$_2$R$_4$,

-NHSO$_2$NHR$_4$,

5   -SR$_4$,

wherein R$_4$ is a C$_2$-C$_{20}$ saturated or unsaturated, straight or branched alkyl group;

Y- is selected from the group consisting of -COO-, PO$_3$H-, -OPO$_3$H-, tetrazolate-5-yl;

10   for the preparation of an antitumor medicament.

A first group of preferred compounds comprises the compounds of formula (I) wherein X is N+(R$_1$, R$_2$, R$_3$), more preferably trimethylammonium. A second group of preferred compounds comprises the compounds of formula (I) wherein two or more R$_1$, R$_2$ and R$_3$, together with the nitrogen atom which

15   they are linked to, form an heterocyclic system, which is preferably selected from morpholinium, pyridinium, pyrrolidinium, quinolinium, quinuclidinium.

A third group of preferred compounds comprises the compounds of formula (I) wherein R$_1$ and R$_2$ are hydrogen and R$_3$ is selected from the group consisting of -CH=NH(NH$_2$), -NH$_2$ and -OH.

20   Within the different embodiments of the present invention, the R$_4$ group is preferably a C$_7$-C$_{20}$ saturated or unsaturated, straight or branched alkyl group. Preferred R$_4$ groups are selected from the group consisting of heptyl, octyl, nonyl, decyl, undecyl, dodecyl, tridecyl, tetradecyl, pentadecyl, hexadecyl, heptadecyl, octadecyl, nonadecyl and eicosyl.

25   Preferred examples of Z group are ureido (-NHCONHR$_4$), and carbamate (-NHCOOR$_4$, -OCONHR$_4$).

The compounds of formula (I) wherein X+, R$_1$, R$_2$, R$_3$, have the above disclosed meanings, Z is ureido (-NHCONHR$_4$) or carbamate (-NHCOOR$_4$,

-OCONHR$_4$), R$_4$ is a C$_7$-C$_{20}$, preferably a C$_9$-C$_{18}$ saturated or unsaturated, straight or branched alkyl group, are particularly preferred.

The compounds of formula (I) have an asymmetry center on the carbon atom bound to a Z group. For the purposes of the present invention, each compound of formula (I) can exist both as R,S racemic mixture and as separate R/S isomeric form.

The compounds of formula (I) are quaternary ammonium or phosphonium derivatives (X+) always containing a Y- anionic group. Depending on pH, each compound of formula (I) can exist indifferently as amphoion (inner salt) or as a compound wherein Y- is present in the YH form. In such a case, X+ is salified with a pharmacologically acceptable acid. Formula (I) covers all these different possibilities.

A group of particularly preferred compounds comprises:

1) R,S-4-trimethylammonium-3-(nonylcarbamoyl)-aminobutyrate;

2) R,S-4-quinuclidinium-3-(tetradecyloxycarbonyl)-oxybutyrate;

3) R,S-4-trimethylammonium-3-(nonylcarbamoyl)-oxybutyrate;

4) R,S-4-trimethylammonium-3-(nonyloxycarbonyl)-oxybutyric acid chloride;

5) R,S-4-trimethylphosphonium-3-(nonylcarbamoyl)-oxybutyrate;

6) R,S-4-trimethylammonium-3-(octyloxycarbonyl)-arninobutyrate;

7) R,S-4-trimethylammonium-3-(nonyloxycarbonyl)-amino butyrate;

8) R,S-4-trimethylammonium-3-octyloxybutyrate;

9) R,S-4-trimethylammonium-3-tetradecyloxybutyrate;

10) R,S-1-guanidinium-2-tetradecyloxy-3-(tetrazolate-5-yl)-propane;

11) R,S-1-trimethylammonium-2-tetradecyloxy-3-(tetrazolate-5-yl)-propane;

12) R,S-3-quinuclidinium-2-(tetradecyloxycarbonyl)-oxy-1-

propanephosphonate monobasic;

13) R,S-3-trimethylammonium-2-(nonylaminocarbonyl)-oxy-1-
propanephosphonate monobasic;

14) R,S-3-pyridinium-2-(nonylaminocarbonyl)-oxy-1–
propanephosphonic acid chloride;

15) R-4-trimethylammonium-3-(tetradecylcarbamoyl)-aminobutyrate;

16) R-4-trimethylammonium-3-(undecylcarbamoyl)-aminobutyrate;

17) R-4-trimethylammonium-3-(heptylcarbamoyl) -aminobutyrate;

18) R,S-4-trimethylammonium-3-(nonylthiocarbamoyl)-
aminobutyrate;

19) R-4-trimethylammonium-3-(nonylcarbamoyl)-aminobutyrate;

20) S-4-trimethylammonium-3-(nonylcarbamoyl)-aminobutyrate;

21) S-4-trimethylammonium-3-(tetradecylcarbamoyl)-aminobutyrate;

22) R,S-4-trimethylammonium-3-tetradecylaminobutyrate;

23) R,S-4-trimethylammonium-3-octylaminobutyrate;

24) R,S-4-trimethylammonium-3-(decansulfonyl)aminobutyrate;

25) R,S-4-trimethylammonium-3-(nonylsulfamoyl)aminobutyrate;

26) S-4-trimethylammonium-3-(dodecansulfonyl)aminobutyrate;

27) R-4-trimethylammonium-3-(dodecansulfonyl) aminobutyrate;

28) S-4-trimethylammonium-3-(undecylsulfamoyl)aminobutyrate;

29) R-4-trimethylammonium-3-(undecylsulfamoyl)aminobutyrate;

30) R-4-trimethylammonium-3-(dodecylcarbamoyl)aminobutyrate;

31) R-4-trimethylammonium-3-(10-
phenoxydecylcarbamoyl)aminobutyrate;

32) R-4-trimethylammonium-3-(trans-b-styrenesulfonyl)aminobutyrate.

The preparation of the compounds of formula (I) is disclosed in the international patent application published under n° WO 99/59957, in the name of the same applicants, which is herein incorporated by reference. Described

therein is the use of the compounds (I) for the treatment of hyperglycaemic states such as diabetes and the pathologies associated therewith. The therapeutic activity of compounds (I) is attributed to an effect of carnitine palmitoyl transferase (CPT) inhibition.

5   In *in vitro* studies on different tumor cell lines, it has surprisingly been found that compounds (I) exert a remarkable antiproliferative and tumoricidal effect which is independent from CPT inhibition, as confirmed by the observation that a known CPT-1 inhibitor, etomoxir, when assayed in the same experimental conditions used for compounds (I), did not show any

10   antiproliferative or tumoicidal activity. The *in vitro* results were subsequently confirmed *in vivo* using animal models of tumor. Also in these conditions, low dosages of compounds (I) proved efficacious in reducing the tumor mass without relevant side effects.

Accordingly, object of the present invention is the use of compounds (I)

15   for the preparation of an antitumor medicament.

The following tumors are preferably treated according to the invention: leukemia, carcinoma, lymphoma, sarcoma, breast, lung, head and neck, rectum and bladder cancers, particularly leukemia and hepatocarcinoma. The therapeutic treatment can be applied at various stages of tumor growth,

20   proliferation and diffusion.

For use in therapy, the compounds (I) may be formulated with pharmaceutically acceptable vehicles and excipients. The compositions according to the present invention are suitable for oral, parenteral, rectal, transdermal and intralesional administration. Examples of oral and parenteral

25   forms include capsules, tablets, granules, powders, syrups and, respectively, solutions and emulsions.

The dosage of compounds (I) may vary depending on the specific product used, on the administration route and on disease progression. A

dosage providing a plasma concentration of active substance from 0.1 to 0.50 μM, preferably 0.5-30 μM, is generally acceptable.

A further aspect of the invention regards pharmaceutical preparations containing a compound (I) in combination with different antitumor agents, for simultaneous, separate or sequential administration to a tumor patient. Examples of antitumor agents that can be used in combination with compounds (I) include cytotoxic or cytostatic compounds, antimetabolites, hormone antagonists, alcaloids, antibiotics, in particular antracyclines, alkylating agents, peptides, agents modifying the biological response, cytokines.

The choice of the specific combination of active substances, of their dosage or administration route, depends on the tumor type, on tumor resistance to pharmacological treatment, on the patient tolerance to the treatment itself and on different variables that will be evaluated on a case by case basis.

The following non-limiting examples illustrate the invention in further detail.

Example 1

In vitro inhibitory effect on proliferation and proapoptotic activity of the compound R-4-trimethylammonium-3-(tetradecylcarbamoyl)-aminobutyrate (ST1326) on human hepatocarcinoma cells (HepG2).

The tumor cell line HepG2 was provided by ATCC (American Type Cell Culture - Mannas, Virginia, acc. no. HB-8065) and subsequently developed in our laboratory. The cells were cultured in complete medium, i.e. MEM added with 10% FCS, 1 mM Na-pyruvate, 2mM L-glutamine, 0.1 mM non essential amino acids and antibiotics (penicillin/streptomycin). The medium, culture products and reagents were purchased from Hyclone-Celbio (Milan, Italy). The cells were seeded in 60 mm-diameter Petri dishes. After

plating the cells were grown for 24 hours prior to their treatment.

In this experiment, increasing amounts of the test molecule were added to hemiconfluent HepG2 cells (Kogure et al., Cancer Chemother. Pharmacol., 2003; DOI. 10.1007/s); the antiproliferative and proapoptotic effects were determined at different times from cell seeding.

The experimental design in some cases provided for the addition of the test compound once the cell culture had been prepared, in other cases the cultures were exposed to the compound every 24 hours after suitably removing the conditioned medium and washing the cells with new (complete) medium. The cells were counted in a Bürker chamber after suitable dilution with a vital dye to visualize the living cells. In particular, the trypan blue exclusion method was used for cell count at 0, 24 and 48 hour treatment. At least 10 cell counts were performed for each experiment and each treatment was carried out in quadruple.

A further analysis involved cytofluorimetry utilizing propidium iodide as a marker for viable cells. The test compound was assayed vs. the CTP inhibitor etomoxir to verify whether the tumoricidal effect could be attributed to CPT-1 inhibition or involved novel mechanisms. The significant data are shown in the Figure.

Surprisingly, the results show that only the compound ST1326 was able to exert an *in vitro* antiproliferative effect associated with a significant tumoricidal activity.

In addition, assays on cell viability were carried out using flow cytofluorimetry techniques. The data reported in Table 1 refer to cells treated only once (time 0); cell mortality (24, 48 and 72 hours) was calculated as the percentage (mean±standard deviation) over 10,000 acquired events.

Table 1

TREATMENT	24 hours	48 hours	72 hours
Control	9.5±1.1	10.2±0.47	11.78±1.9
Etomoxir 5 μM	10.8±1.65	11.8±0.4	10.1±2.1
Etomoxir 20 μM	13.04±1.07	11.2±1.3	11.7±1.3
ST1326 0.1 μM	15.3±2.1	27.3±2.2	49.9±1.2
ST1326 5 μM	25.78±1.70	56.29±1.51	93.48±1.5
ST1326 10 μM	53.21±1.5	85.10±0.9	96.3±1.1
ST1326 20 μM	88.22±1.9	89.10±0.17	98.51±1.3

In further experiments the test molecule was added every 24 hours, as above described, after suitably removing the surnatants and washing the cultures with complete medium. In this case, the subsequent additions of the test molecule showed an additive effect on cell viability (Table 2). In the control, the surnatant was eliminated and complete medium alone was added to the cultures. Cell mortality (at 48 and 72 hours) was calculated as the percentage (mean ± standard deviation) over 10.000 acquired events.

Table 2

TREATMENT	48 hours*	72 hours**
Control	9.3±1.3	13.06±1.5
Etomoxir 5 μM	10.17±1.7	12.6±1.1
Etomoxir 20 μM	13.9±1.2	14.1±0.9
ST1326 0.1 μM	45±2.0	56.5±1.2
ST1326 5 μM	64.7±1.7	89.7±1.4
ST1326 10 μM	87.5±2.03	91.3±1.9
ST1326 20 μM	93.9±1.03	98.1±0.9

*: second addition of the test molecule after eliminating the surnatant;

**: third addition of the test molecule after eliminating the surnatant.

Example 2

***In vitro* proapoptotic activity of the compound ST1326 on acute**

5   **leukaemia T cells (Jurkat).**

The tumor cell line Jurkat was provided by ATCC (American Type Cell Culture - Mannas, Virginia, acc. No. TIB-152) and subsequently developed in our laboratory. The cells were cultured in complete medium containing RPMI 1640 added with 10% FCS (bovine fetal serum), 1 mM

10 Na-pyruvate, 2 mM L-glutamine, 4.5 g/L glucose, 10 mM HEPES and antibiotics (penicillin/streptomycin). The medium, culture products and reagents were purchased from Hyclone-Celbio (Milan, Italy). The cells were seeded in 25 mm^2 flasks. After plating the cells were grown for 24 hours prior to their treatment.

15 The experiment was carried out by adding increasing amounts of the test molecule to hemiconfluent Jurkat cells; the proapoptotic effect was determined at different times from culture preparation.

The experimental design provided for the addition of the test compound only at the start of cell culturing, and the determination of the effects at the

20 established times. The data on cell mortality were obtained using propidium iodide flow cytofluorimetry techniques only. The fact that those cells live suspended in culture rendered these assays extremely easy to perform.

Table 3 shows that the Jurkat cells are extremely more sensitive than HepG2 cells to the tumoricidal action of the compound. For this reason the cell

25 mortality was determined just after 2 hour treatment and at 24, 48 and 72 hrs.

The mortality was calculated as the percentage over 10.000 acquired standard events. Since the results are almost exactly overlapping, with very low deviation in all the readings for each single experiment, the mean values

of 5 cytofluorimetric readings are reported in the following Table without
standard deviation.

Table 3

TREATMENT	2 hours	24 hours	48 hours	72 hours
Control	3%	4%	5%	13%
ST1326 0.1 µM	3%	4%	5%	13%
ST1326 0.25 µM	3%	5%	8%	14%
ST1326 0.50 µM	7%	15%	35%	56%
ST1326 1.0 µM	6%	79%	83%	90%
ST1326 2.5 µM	6%	91%	97%	99%
ST1326 5.0 µM	8%	99%	99%	99%
ST1326 10 µM	20%	99%	99%	99%

5

In addition, in order to exclude the induction of toxicity in normal PBMCs
by the test molecule, viability tests were also carried out with lymphocytes taken
from healthy individuals and contacted with the test compound.

The results reported in Table 4 show that the test compound after 72 hours
10   was not toxic to PBMCs at the same doses that proved able to kill Jurkat cells.

Table 4

TREATMENT	72 hours
Control	9%
ST1326 1.0 µM	9%
ST1326 5.0 µM	10%
ST1326 10 µM	10%
ST1326 20 µM	12%

Example 3

In vitro antagonistic activity of sub-optimal doses of ST1326 compound on the antineoplastic effects of doxorubicin on human hepatocarcinoma cells (HepG2).

5   The tumor cell line HepG2 was provided by ATCC (American Type Cell Culture - Mannas, Virginia, No. HB-8065) and subsequently developed in our laboratory. The cells were cultured in complete medium containing MEM added with 10% FCS (bovine fetal serum), 1 mM Na-pyruvate, 2 mM L-glutamine, 0.1 mM non-essential amino acids and antibiotics (penicillin/streptomycin). The

10   medium, culture products and reagents were purchased from Hyclone-Celbio (Milan, Italy). The experimental design provided for the use of ST1326 and of known antineoplastic drugs, such as doxorubicin, against which the HepG2 cells show a high resistance, to determine the **agonist** action of the compound. The ST compound was used at a concentration that in prior experiments proved only

15   partially able to induce a tumoricidal effect (0.1 µM; ~50% cell mortality). In this experiment, the following compounds were added to hemiconfluent HepG2 cells in 96 well plates:

-      0.25, 0.5, 5.0 µg/mL doxorubicin;

-      0.1 µM ST in combination with 0.25 µg/mL doxorubicin.

20   After 24 hr incubation, the medium containing different concentrations of doxorubicin and the ST/doxorubicin combination was removed and the cells were washed with complete medium. After 3-day treatment, the antineoplastic effect of the test compound was determined in comparison with control cells incubated in complete medium for the same period of time.

25   Table 5 shows that only the highest dose of doxorubicin (5.0 µg/mL) is able to induce a significant cell mortality. The addition of ST and doxorubicin at concentrations of 0.1 µM and 0.25 µg/mL, respectively, allowed to demonstrate the **agonist** tumoricidal effect of their combination. The cell mortality was

calculated as the percentage (mean ± standard deviation) over 10.000 acquired events.

Table 5

TREATMENT	3 days
Control	10.8±1
Doxorubicina 0.25 μg/mL	11.2±1.5
Doxorubicina 0.5 μg/mL	22.7±3.5
Doxorubicina 5.0 μg/mL	48.6±4.1
ST1326 0.1 μM + Doxorubicina 0.25 μg/mL	93.2±2.7

5

Example 4

In vivo **antineoplastic activity of the ST1326 compound in rats bearing Yoshida tumor.**

Male Wistar rats (Morini s.r.l.) of 190-200g weight were maintained at
10   22±2°C, with a light/dark cycle of 12 hours, and were given free access to water and food (standard diet). Some rats were intraperitoneally inoculated with 10×10^7 cells from AH-130 Yoshida ascites hepatoma (Llovera et al., Int. J. Cancer 61:138-41 (1995); kind gift from Prof. JM Argilès). 5-7 days after the inoculum, the rats developed an ascites that could be detected by
15   macroscopic analysis of the abdomen. The paracentesis revealed the presence of approximately 80-100 ml ascitic fluid, which sometimes appeared hemorrhagic, containing on average $15\text{-}20 \times 10^6$/ml tumor cells.

The experimental protocol provided that 7 days after ascites induction
15 animals (treated group) received 2 ml of a buffered saline containing ST

(25 mg/Kg i.p.), whereas other 15 animals (control group) received the buffered saline alone. The same treatment was conducted at alternate days for one week up to a total of 4 treatments for each animal. The dosage was selected on the basis of preliminary studies in which a 6.1 µM plasma

5   concentration of ST was achieved 5 hr after intraperitoneal administration. The animals were subsequently kept under observation for 3 weeks (follow-up), examining the ascites effusion, the presence of subcutaneous neoplastic mass in the inoculum site, and the mortality.

The most interesting observation was that the treated animals survived

10   during the 3-week follow-up period, whereas the control rats died between the first and the second week.

The post-mortem examination of the control animals showed the presence of ascitic fluid containing tumor cells in the abdominal cavity, hyperplasia of intestinal Peyer plaques, absence of tumor lesions involving the

15   abdominal organs and finally the development of a tumor lesion close to the muscle fascia in the site of inoculum of the neoplastic cells. The treated rats were sacrificed at the end of the third week and their post-mortem examination failed to reveal any alteration in the abdominal cavity, or the presence of tumor cells in the ascitic fluid or in the inoculum site.

20   A synopsis of the experimental data/results is shown in the following Tables 6 and 7.

25

Table 6

	Survival at 1 week follow-up	Survival at 2 week follow-up	Survival at 3 week follow-up
No. of survived animals treated with buffered saline (No)	11	1	0
No of survived animals treated with ST1326	15	15	15

Table 7

5

	Presence of tumor cells in the abdominal cavity (post-mortem examination)	Presence of tumor mass in the inoculum site	Presence of cachexy
No. of animals treated with buffered saline	15	10	15
No. of animals treated with ST1326	0	0	1

The experimental results obtained with oral and i.v. administration showed the efficacy of the treatment at different dosages of the test compound (oral route: 100mg/Kg; i.v.: 2mg/Kg).

Brief description of the Figure

10   The data relating to cell viability are expressed as percentage on the number of viable cells from control cultures (=100%). (E = etomoxir; ST1326 = tested compound). A remarkable reduction in the number of cells cultured in the presence of less than 10 µM ST was observed just after 24 hours. At the same concentrations etomoxir was ineffective.

15